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(54) ELECTROLUMINESCENT P.N. JUNCTION DEVICE

(71) We, RCA CORPORATION, a corporation organised under the laws of the State of Delaware, United States of America, of 30 Rockefeller Plaza, City and State of New York 10020, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an electroluminescent P.N. junction device. More particularly this invention relates to an electroluminescent device which emits radiation outside of the visible spectrum and which includes means for visibly indicating that the device is operating.

Electroluminescent semiconductor elements are known which exhibit electroluminescence in the vicinity of a P.N. junction which is biased so as to inject charge carriers of one type into a region where the predominant charge carriers are of the opposite type. Radiation is emitted in conjunction with the combination of pairs of oppositely charge carriers. Depending on the construction of the electroluminescent semiconductor element and the material it is made of, the frequency of the radiation emitted by the element may be in the visible spectrum radiation or may be outside the visible spectrum, such as infrared radiation.

In the use of the electroluminescent semiconductor device it is desirable to be able to determine whether the device is emitting radiation when the current is applied to the device. If the device is of the type which emits radiation in the visible spectrum, there is no problem in making this determination since the radiation can be seen. However, if the device is of the type which emits radiation outside of the spectrum, this determination cannot be made without the use of special equipment for detecting the particular type of radiation. Therefore, it would be desirable to have an electroluminescent semiconductor device which emits radiation outside of the visible spectrum which provides a visible indication that it is emitting the radiation.

[*Price 25p*]

According to the invention, we provide an electroluminescent device for emitting radiation outside the visible spectrum comprising a P.N. junction type electroluminescent semiconductor element for emitting radiation outside of the visible spectrum, means encapsulating the semiconductor element, said encapsulating means being transparent to the radiation emitted by the semiconductor element and to radiation within the visible spectrum, and means within the encapsulating means comprising a phosphor material for converting a small portion of the radiation outside of the visible spectrum emitted by the semiconductor element to radiation within the visible spectrum and for emitting such radiation within the visible spectrum while allowing the remainder of the radiation outside the visible spectrum to be emitted from the electroluminescent device, the emitted radiation within the visible spectrum providing an indication that the electroluminescent device is emitting radiation outside the visible spectrum.

The drawing is a sectional view of a form of the semiconductor device of the present invention.

Referring to the drawing, a form of the electroluminescent device of the present invention is generally designated as 10. Electroluminescent device 10 comprises a support 12, which is shown to be a flat metal disk. A P.N. type junction electroluminescent semiconductor element 14 of a type which emits radiation outside of the visible spectrum, such as infrared radiation, is mounted on the top surface of the support 12 and is secured thereto by a suitable solder. The electroluminescent element 14 may be of any construction well known in the art. The electroluminescent element is made of a semiconductor material having a band gap energy which provides radiation outside the visible range such as gallium arsenide, indium phosphide or a mixture of indium arsenide and gallium arsenide, and includes adjacent P type and N type regions 16 and 18 with a P.N. junction 20 therebetween. The element exhibits electroluminescence in the vicinity of the P.N.

junction 20 when the element is biased so as to inject charge carriers of one type into a region where the predominant charge carriers are of the opposite type. Radiation is emitted in conjunction with the combining of pairs of oppositely charged carriers. The element 14 is mounted on the support 12 so that the radiation from the element is emitted away from the support.

A terminal wire 22 extends through an opening in the support 12 and projects slightly above the top surface of the support. The terminal wire 22 is secured to and electrically insulated from the support 12 by a washer 24 of an electrically insulating material, such as glass or ceramic. The terminal wire 22 is electrically connected to a contact on the P type region 16 of the element 14 by a fine wire 26. Another terminal wire 28 is secured to the support 12 which is electrically connected to a contact on the N type region 18 of the element 14.

An encapsulation dome 30 is mounted on and secured to the top surface of the support 12. The dome 30 extends over and is in intimate contact with the electroluminescent element 14 so that the element is encapsulated within the dome and the radiation emitted from the element passes through the dome. The dome is of a material which is transparent to the radiation emitted by the electroluminescent element 14, radiation outside of the visible spectrum, and to radiation within the visible spectrum, which preferably has a high index of refraction and which can be easily formed around the element. Plastics, such as the epoxy, acrylic, polyester or glycol phthalate plastics, and low melting glasses can be used for the encapsulating dome 30.

Dispersed throughout the encapsulation dome 30 are particles 32 of a phosphor which will emit radiation in the visible spectrum when subjected to the radiation outside of the visible spectrum emitted by the electroluminescent element 14. The phosphors which are most suitable for this purpose are those which when subjected to radiation of a frequency outside the visible spectrum, such as infrared radiation, will emit visible light by a two or three photon absorption process. Such phosphors include ions of rare earth crystals, such as ytterbium and erbium or ytterbium and holmium, in a host material, such as LaF_3, Y_2OCl_7, $BaYF_5$ or $BaLuF_5$. The amount of the phosphor 32 included in the encapsulation dome 30 should be enough to provide a visible emission of light from the phosphor without adversely affecting the desired output of the radiation from the electroluminescent element 14. It has been found that a mixture of the material of the encapsulation dome 30 and the phosphor particles 32 in which the phosphor particles are present in the amount of 0.5% to 1% by weight will provide a visible emission of radiation from the phosphor particles without adversely affecting the emission of radiation from the electroluminescent element 14. However, it should be understood that a greater quantity of the phosphor can be included in the encapsulation dome 30 if the output of the emission from the electroluminescent element 14 is considerably greater than the output required for the particular use of the electroluminescent device 10.

The encapsulation dome 30 with the phosphor particles 32 is formed on the electroluminescent device 10 by first mixing together the material of the dome and the phosphor particles. The mixture is then molded on the top surface of the plate 12 and over the electroluminescent element 14 in a manner suitable for the particular material being used for the encapsulation dome. Although the encapsulation dome 30 is shown as being solid, it can be a hollow cupshaped member mounted on the plate 12 and covering the electroluminescent element 14. For such a hollow dome, the phosphor particles 32 can be either embedded in the wall of the dome or coated on the inner surface of the dome.

In the use of the electroluminescent device 10, the electroluminescent semiconductor element 14 is suitably biased by connecting the terminals 22 and 28 across a source of electrical current to cause the element to emit the radiation which is outside of the visible spectrum. The radiation emitted by the element 14 passes into the encapsulation dome 30. A small portion of the radiation from the element 14 is absorbed by the phosphor particles 32 in the encapsulation dome 30 while the major portion for the radiation passes through the dome and is emitted from the electroluminescent device 10. The portion of the radiation absorbed by the phosphor particles 32 causes the phosphor particles to emit radiation in the visible spectrum which also passes through the dome. The color of the radiation emitted by the phosphor particles will depend on the particular composition of the phosphor being used. Thus, when the electroluminescent device 10 is emitting radiation outside of the visible spectrum, the phosphor particles will emit radiation within the visible spectrum so as to provide the use of the device with an indication that the electroluminescent device 10 is properly operating.

WHAT WE CLAIM IS:—

1. An electroluminescent device for emitting radiation outside the visible spectrum comprising a P.N. junction type electroluminescent semiconductor element for emitting radiation outside of the visible

spectrum, means encapsulating the semiconductor element, said encapsulating means being transparent to the radiation emitted by the semiconductor element and to radiation within the visible spectrum, and means within the encapsulating means comprising a phosphor material for converting a small portion of the radiation outside of the visible spectrum emitted by the semiconductor element to radiation within the visible spectrum and for emitting such radiation within the visible spectrum while allowing the remainder of the radiation outside the visible spectrum to be emitted from the electroluminescent device, the emitted radiation within the visible spectrum providing an indication that the electroluminescent device is emitting radiation outside the visible spectrum.

2. An electroluminiscent device as claimed in claim 1, wherein the phosphor is of the type which emits visible light by a two or three photon absorption process when subjected to radiation outside of the visible spectrum.

3. An electroluminescent device as claimed in claim 1 or 2, wherein the phosphor material is dispersed throughout the encapsulating means.

4. An electroluminescent device as claimed in claim 4, wherein the phosphor material is present in an amount of from 0.5 to 1% by weight of the mixture of the phosphor material and the encapsulating means.

5. An electroluminescent device as claimed in claim 1, 2 or 3, wherein the encapsulating means is a hollow dome which carries on its interior surface said phosphor material for emitting radiation within the visible spectrum.

6. An electroluminescent device as claimed in any one of the preceding claims, wherein said P.N. junction type semiconductor element emits infrared radiation and said phosphor material within the encapsulating means converts infrared radiation to radiation within the visible spectrum.

7. An electroluminescent device substantially as herein before described with reference to the accompanying drawings.

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1 SHEET This drawing is a reproduction of the Original on a reduced scale